An Interactive Story Map for the Methana Volcanic Peninsula

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Abstract: The purpose of this research is the identification, recording, mapping and photographic imaging of the special volcanic geoforms as well as the cultural monuments of the volcanic Methana Peninsula. With the use of novel methods the aim is to reveal and study the impressive topographic features of the Methana geotope and discover its unique geodiversity. The proposed hiking trails along with the Methana's archaeology and history, will be highlighted through the creation of an 'intelligent' interactive map (Story Map). Two field trips have been conducted for the collection of further information and the digital mapping of the younger volcanic flows of Kammeni Chora with drones. Through the compiled data, thematic maps were created depicting the lava flows and the most important points of the individual hiking paths. The thematic maps were created using a Geographic Information System (GIS). Finally, those maps were the basis for the creation of the main Story Map. The decision to use Story Maps was based on the numerous advantages on offer such as user-friendly mapping, ease of use and interaction and user customized displays.

1 INTRODUCTION

Recent advancements in digital Geographic Information Systems (GIS) technologies can provide new opportunities for immersively engaging public audiences with complex multivariate datasets.

Story Maps can be not only robust but also versatile tools for visualising spatial data effectively and when combined with multi-media assets (e.g. photos or videos) and narrative text, they can provide support for scientific storytelling in a compelling and straightforward way.

Thereby, Story Maps can be used in order to disseminate and make scientific findings easy to access and understand to broader non-technical audiences (Janicki, J. et al., 2016; Wright, D.J. et al., 2014).

The aim of the present research is to identify, record, map and photographically image the special volcanic geomorphs as well as the cultural monuments of the Methana Peninsula (East Peloponnese, Greece).

Methana peninsula is composed by 32 volcanic craters with rough topography, belonging to the western part of the Hellenic Volcanic Arc. Using Story Maps along with novel methods and research tools it is planned to reveal and highlight the peculiar geomorphs of the Methana geotope and discover its unique geodiversity.

Adopting Story Maps for this work offers a number of advantages as compared to traditional methods: friendly mapping, the ease of use and understanding of the provided information, the increased interactivity comparing to analogue or simple web maps, the customized display based on the user's needs, the ability to import different kind of media (images and videos) and ultimately the ability to add explanatory text covering a wide range of heterogeneous information.

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2 STUDY AREA

The Methana volcanic peninsula (Methana Volcano) is located at the Western Saronic Gulf, approx. 163Km from Athens, covering an area of 50Km². Methana Volcano is at the western part of the Aegean volcanic arc extending from Saronic Gulf up to Kos-Nisyros volcanic field at the eastern part (Fig. 1). The Aegean volcanic arc belongs to the Hellenic Orogenic Arc, which is formed along the convergent plate boundary of the northwards subducting African plate underneath the active margin of the European plate (Nomikou et al., 2013). The peninsula of Methana has the longest recorded volcanic history of any volcanic centre in the Aegean Volcanic Arc, consisting of 30 volcanic cones. Particularly noteworthy are the historical references regarding the volcanic activity of the submarine volcano Pausanias, lying offshore the northwest part of Methana peninsula (Pavlakis et al., 1990), in the 3rd century BC.

Throughout Methana peninsula there is a well-developed network of hiking trails, passing through historic settlements, small churches, hot springs and unique geomorphological features attributed to the volcanic history (lava formations) and the complex tectonic regime of the area (Pe-Piper and Piper, 2013). The overall length of the hiking network is approximately 60Km, and based on the present study the hiking distances range between 0.5Km up to 5Km. Moreover, the trails are rated into different difficulty levels and in several cases appropriate equipment is needed.

Volcanic activity in the area is considered to have begun in the late Pliocene (Gaitanakis and Dietrich, 1995), and the last eruption took place in 230 BC giving andesitic lava, at Kammeni Hora, as recorded by the ancient geographer Strabo (Georgalas, 1962).

The Quaternary volcanic rocks on Methana consist of domes and flows radiating from the central part of the peninsula, overlying older, undated volcanic rocks (inferred Pliocene or early Pleistocene in age). At a map scale, many of the domes are elongated in an east–west or northeast–southwest direction. The volcanic style and rate of eruption are closely related to periods of change in regional tectonic style (Pe-Piper and Piper, 2013).

Moreover, Pe-Piper and Piper (2013) deciphered the volcanological evolution of the Volcano in great detail based on geochemical, geochronological analyses and field observations. The following volcanic history has been identified (Fig. 2):

- **Phase A.** Late Pliocene. Small domes of andesite and dacite were extruded on N–S-striking faults in eastern and southern Methana. Either synchronously or later, a larger volcanic edifice grew somewhere near the present centre of the peninsula.
- **Phase B.** Erosion of the central edifice to form the volcanoclastic apron, perhaps associated with faulting and uplift.
- **Phase C.** Eruption of basaltic andesite now preserved in northern Methana around Kounoupitsa, at Ag. Andreas and Akri Pounda. A series of explosive Plinian eruptions deposited in the northern and eastern parts of the volcanoclastic apron and at Akri Pounda. Erosion of the central edifice and volcanoclastic deposition on the apron continued. The age of phase C is poorly constrained — the 1.4 ± 0.3 Ma date on a dome in northern Methana is only tentatively correlated with this phase.
- **Phase D.** Andesite flows in the north-western part of the peninsula and dacites in the south show some geochemical similarities to phase C (e.g. high TiO_2 content), but overlie the volcanoclastic apron and its associated erosion surface in eastern Methana. Imprecise radiometric dates range from 0.5 to 0.9 Ma.
- **Phase E.** The north-western dacite volcanoes were formed and are dated at 0.6 ± 0.2 Ma in this study.
- **Phases F and G.** These phases were characterised by the eruption of the central andesite volcanoes and the E–W fissure dacites. Some explosive pyroclastic eruptions preceded major andesite and dacite eruptions. Available radiometric ages from phase G cluster between 0.29 and 0.34 Ma.
- **Phase H.** Eruption of the Kammeni Hora flows, probably within the last 0.2 Ma, with the most recent eruption in historic times.

2.1 Geomorphology

Methana peninsula is characterized by rough topography, generated by the complex regional tectonic regime in combination with the volcanic activity. The mountainous relief of the peninsula, 740 masl at its highest point, falls to the sea with no lowland plain. Abrupt and sudden changes in slope gradient alternate with flat basinal areas (Fig. 3) filled by Quaternary sediments, where at the same time volcanic agglomerates commonly fill depressions between domes (James et al.,1994). Moreover, the volcanic landforms are dissected by stream gullies, reflecting the intense erosion. This rugged terrain, with the well-developed drainage system and the steep slopes, is prone to landslides and rockfalls induced by geomorphologic and geologic controls.

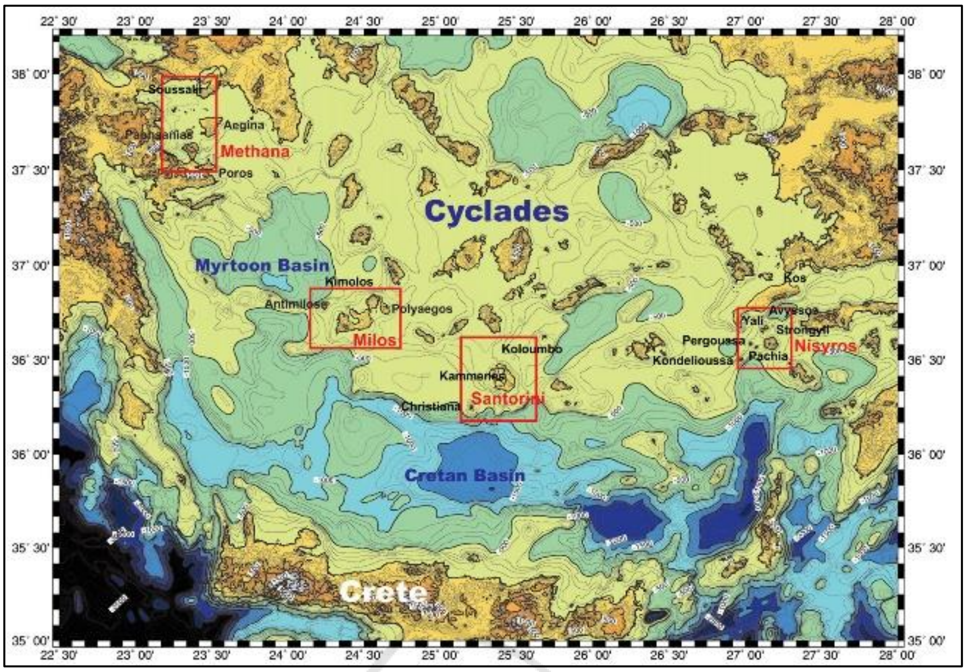

Figure 1: Topographic map of the southern Aegean Sea combining onshore and offshore data. The four modern volcanic groups are indicated within red boxes together with the names of the main terrestrial and submarine volcanic centers along the volcanic arc (Nomikou et al., 2013).

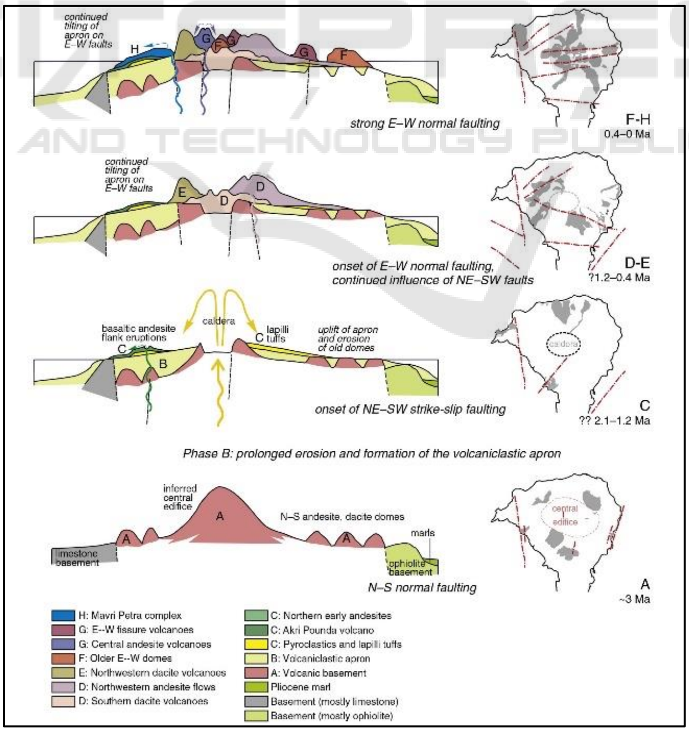

Figure 2: Schematic cross-sections (E–W or SE–NW) and maps of Methana, showing inferred relationship of volcanic stratigraphy to evolution of regional fault patterns. Cross sections illustrate stratigraphy; no representation of the magmatic plumbing system is attempted (Pe-Piper and Piper, 2013).

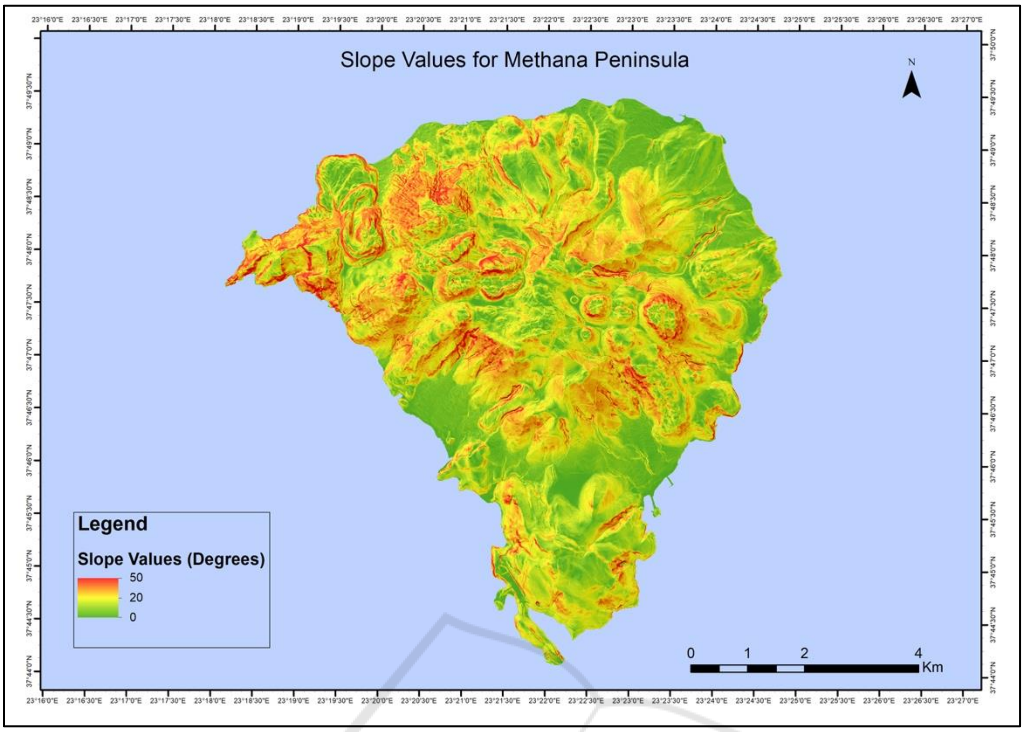

Figure 3: Morphological Map of Methana peninsula.

3 DATA COLLECTION

To tackle the challenge of creating the Story Map of Methana volcanic peninsula, different types of datasets have been collected (Fig. 4). All the available literature regarding the geology, geodiversity, archaeology and biodiversity has been compiled and geospatial data have been downloaded from open source portals. Moreover, two field trips took place in September in order to acquire field data.

3.1 Field Trips

Two field trips have taken place in order to collect new photographic material, to trace paths and find places of special interest, attaching representative photographs or videos, etc. In order to collect all these new data, up – to – date technology has been used which is the Collector for ArcGIS software and GPS. Furthermore, an aerial campaign with an unmanned aerial vehicle (UAV) was conducted. A commercial, off-the-shelf quadrocopter (DJI Phantom 4 Pro Plus) was used with a 21 MP digital RGB camera from University of Portsmouth and up2metric Company. Flights were performed at different areas of interest, over the City of Methana, the Kammeni Chora village and the volcanic formations at the western part of Methana. There, video sequences and images at constant time intervals were captured, to guarantee a higher than 80% image overlap (Fig. 5).

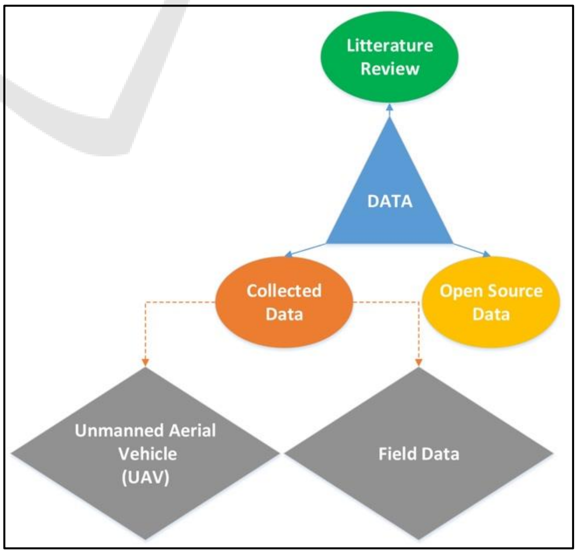

Figure 4: Chart showing the different types of datasets used in this study.

Figure 5: Photo taken during the fieldtrips capturing Methana Volcano.

4 METHODOLOGY

4.1 References

For the present research, a geo-database was created, which is the systematic collection of the existing information for the study area into a user – friendly and functional system in order to support effective ways for data visualisation. Specifically, our database was divided into two subsets of data. The first subset consists of the available data files for the area (bibliography, topographic map, geological – tectonic structure etc.). Those that were in analogue form were converted into digital form, in order to make further use of them. This subset also includes the vector data files that have been designed for the data collection in the field work. The second subset consists of the data files that resulted from the processing of the aforementioned, or their modification with new field data, and these are the files that thematic maps were based on. These files were gradually transformed into a format suitable for online use (feature or image services) and easily applied to the Story Map.

4.2 Field Data Collection

A Geographical Information System, ArcGIS platform from ESRI Company, with both desktop and online applications, was used to accomplish this study (https://www.esri.com/). The creation of information layers, including existing and new data, has been performed through ArcMap v.10.5.1 software ("ArcGIS for Desktop – ArcMap," n.d.). In addition, ArcGIS Online ("ArcGIS Online - ArcGIS Online Help," n.d.) has been used in order to construct the online map (webmap) on which collected data would be presented. Finally, Collector for ArcGIS, ("ArcGIS Collector," n.d.), both compatible for Android and iOS software, has been used for the data collection. This application supports functionality, to collect and update spatial and descriptive data through mobile devices (tablets or smartphones). More specifically, these advantages are:

- Convenient collection of points, lines and elements that cover a large area.
- Data collection and update using the map or the GPS signal.
- Photos and videos attachments confirming the collected descriptive data.
- Capability to download maps in a mobile device and use of them even with no internet access.
- Capability of monitoring specific areas and report composition about them.

In more detail, the methodology unfolds as follows (Fig. 6):

Firstly, collection and organization of existing vector and grid data was carried out as well as their spatial and descriptive analysis, if necessary. For this purpose, a geodatabase has been created via ArcMap v.10.5.1 software, in which all information layers that would also appear on the online map have been added, including the editable ones.

Each of the information layers hosts apart from the type of the spatial information all the necessary fields for the descriptive information. This information would be either the already existing one or the one that would be collected during field work.

The pre-existing information layers include coastline, settlements, geological formations (Fig. 7) and tectonic structures of the island. Two editable information layers have been created, for the field data collection (Fig. 8). One point and one polyline vector file, which apart from spatial information they will also include descriptive information and photos or video for each collected feature.

In the second part of this study, information layers were uploaded in the online platform of ArcGIS and have been converted to feature services, a file type that can show information online (https://goo.gl/mBTiKF).

In the next step, a webmap and the individual parameters for each of the information layers, e.g. its symbol and the appearance or not of tags and pop-up menus etc., have been created (DiBiase et al., 1992; Newman et al., 2010). Moreover, a refresh interval for the information layer regarding data collection has been defined. Specific symbols for each user group have been created, so that each group can directly be identified. Imagery, which is available from ArcGIS platform, was assigned to be the background of the above information layers.

In this research, GIS technology was used only to collect, analyse and visualize data, using desktop and online interactive techniques, because its main aim was to disseminate this way of data presentation to the public, combining scientific information about the volcanic peninsula with archaeology and history.

4.3 UAV Survey

The acquired video samples were used to create small demonstration videos and panoramic photos. Still images, captured at constant time intervals to guarantee a higher than 80% overlap, were also used to generate photogrammetric 3D textured models. For the latter, the drone camera was calibrated and all images were oriented with a standard Structure-From-Motion (SFM) approach. This procedure includes the establishment of sparse multi-image point correspondences. This is achieved by 2D feature extraction and matching among images, employing feature descriptors at multiple image scales. The point correspondences were filtered through standard RANSAC outlier detection and all mismatched points were identified and eliminated. Image orientations were initialized through closed form algorithms and finally optimal estimations of exterior and interior orientation parameters were computed through a standard self-calibrating bundle adjustment solution.

After image orientation, dense point clouds were generated by means of dense stereo and multi-image matching algorithms. Through 3D triangulation, the 3D point clouds were converted to 3D mesh models. Photorealism was finally achieved by computing texture for each 3D triangle via a multi-view algorithm, using a weighted blending scheme. Photorealistic texture was estimated by means of interpolation, using all images which view each particular surface triangle (Fig. 9). The photogrammetric processing was performed using the Pix4DMapper commercial software, assisted by own developed algorithms for dense stereo matching (Stentoumis et al., 2014) and the refinement of the 3D model's texture (Karras et al., 2007).

5 STORY MAP

In order to compose this Story Map, all the available information was uploaded to the online platform. Users have the possibility to either using a private server or uploading information directly to ArcGIS Online. The latter approach was followed during the deployment of this Story Map (Fig. 10).

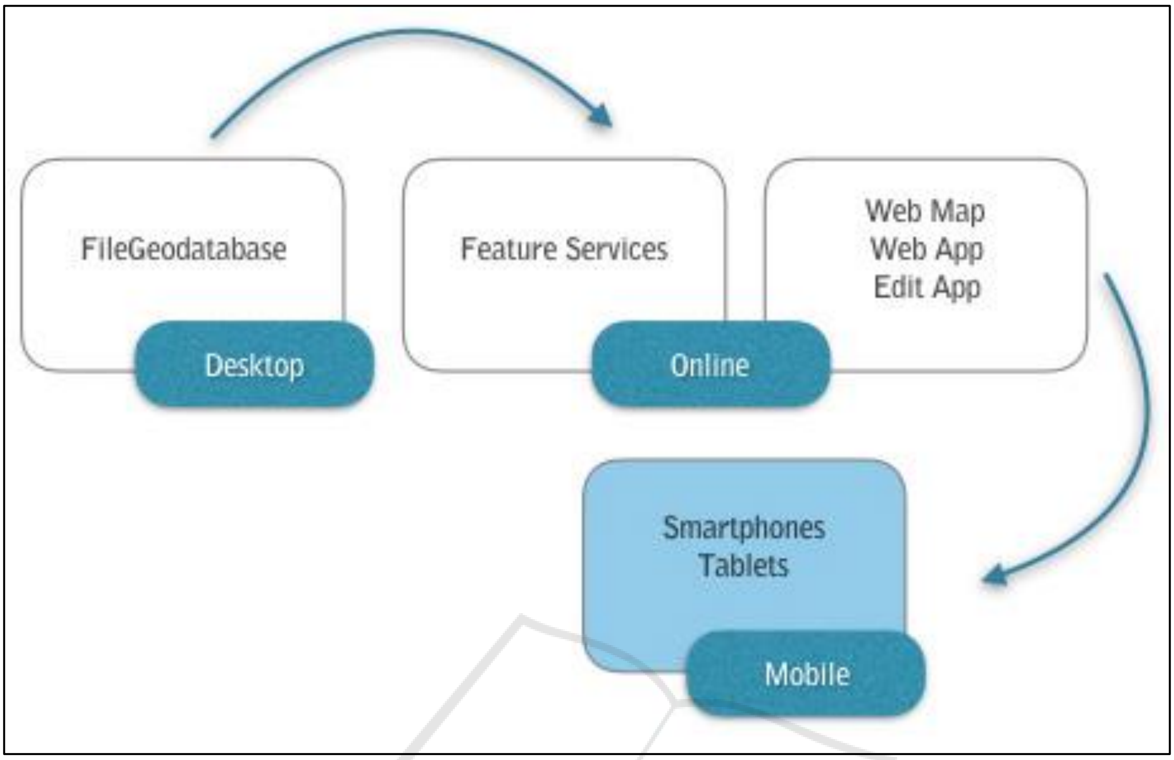

Figure 6: Workflow to be followed in order to use mobile devices for collecting data via Collector for ArcGIS application.

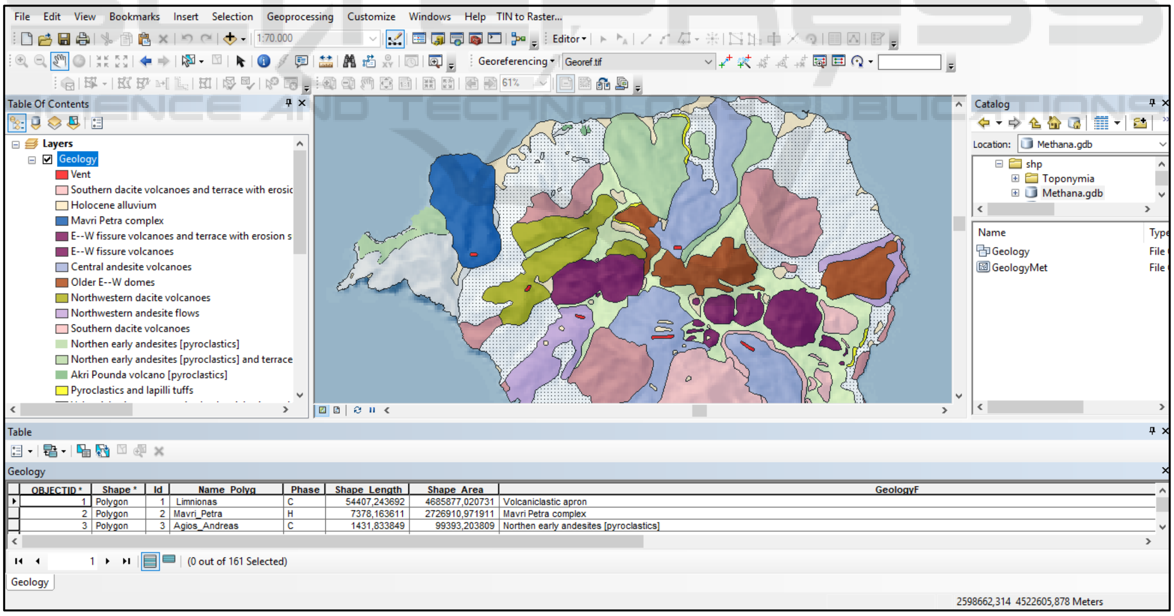

Figure 7: Screenshot of ArcGIS Desktop 10.5.1, which shows the geological information (spatial and descriptive) for the area.

Figure 8: Screenshot which shows data that have been collected during field trips.

Figure 9: Photogrammetric 3D image of Nisaki (Methana peninsula).

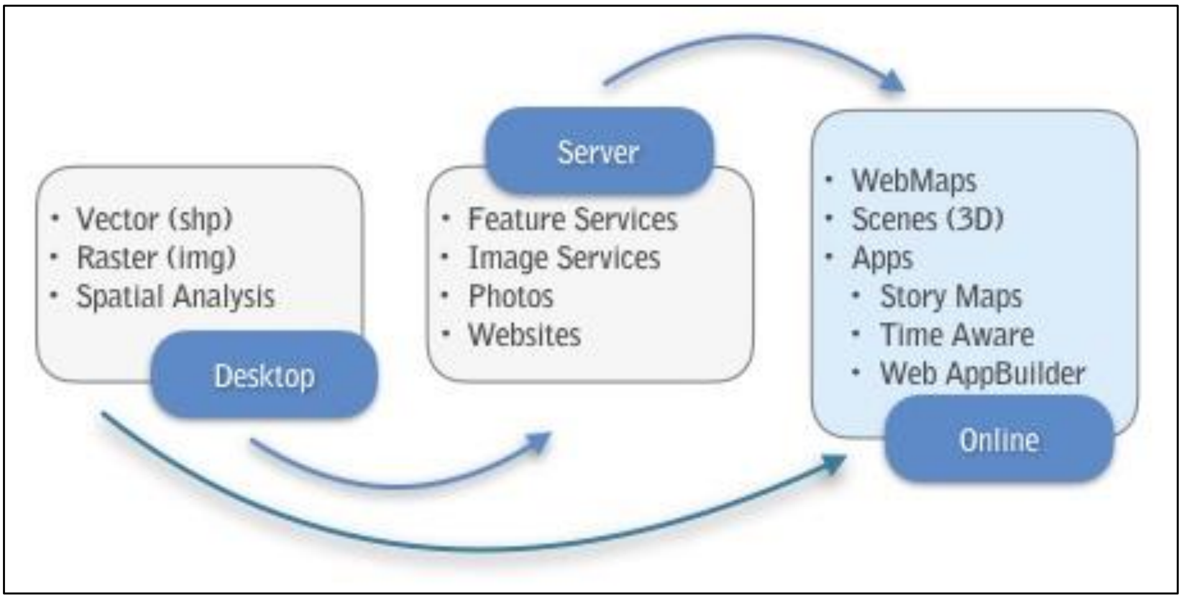

Figure 10: Workflow highlighting the procedure followed to produce a Story Map (Antoniou, 2015).

A certain template, called Story Map Series was implemented, to present the available information. Story Map Series comes with three layout options: tabbed, side accordion and bulleted. The first one was selected for the main Story. Web maps, narrative text, images, tables, video, external websites, scenes which correspond to 3D presentation of data were used. Also, other Story maps and apps were embedded, such as Story Map Shortlist, Story Map Series-Side Accordion and Time Aware. Finally, Story Map Cascade was used as a home page (Fig. 11).

Thematic maps were created in ArcGIS online and were based on the collected data, the fieldwork and literature review, depicting the most important and unique points. More specifically:

First tab using Story Map Series-Side Accordion, gives general information about Methana peninsula, containing the geographical position and geomorphology and a brief description of the area's points of interest. Text is accompanied by webmaps showing the spatial distribution of these having as basemap, imagery from ESRI's basic gallery maps (Fig. 12).

Second tab presents the geological setting of the peninsula. Text explains the volcanic activity of the area and in addition an embedded Time Aware application presents the geological-volcanic evolution of the island. As basemap, a 5m-hillshade of the area was used and a Scene (3D presentation) was created.

Next three tabs present the main hiking trails in the area. Story Map Tour application was embedded in each one of them. Text describes the morphology of the path and gives detail information for every point of interest and a webmap gives the spatial distribution of them. Users are able to select either a point in the map or a photo - video from the carousel and gather further information.

Last tab, indicates the Research Team responsible for the creation of this Story Map.

Finally, in order to give users, the ability to choose the language they prefer, a Story Map Cascade was used to be Story Map's home page.

6 CONCLUSIONS

The use of Story Map has plenty of advantages since it presents useful and attractive information about the study area. The use of explanatory text and the incorporation of multi-media helps the end user to engage in scientific knowledge transfer and provides a better understanding of Methana's volcanic geodiversity.

The user of the Story Map can navigate easily through the content, by pop - ups, swipe up and down and through slides. As it is user - friendly, the interface can be customized according to the user's display screen (mobile phones, computers or tablets) and every single user has the ability to customize the application to his needs (for example, unveiling specific volcanic cone).

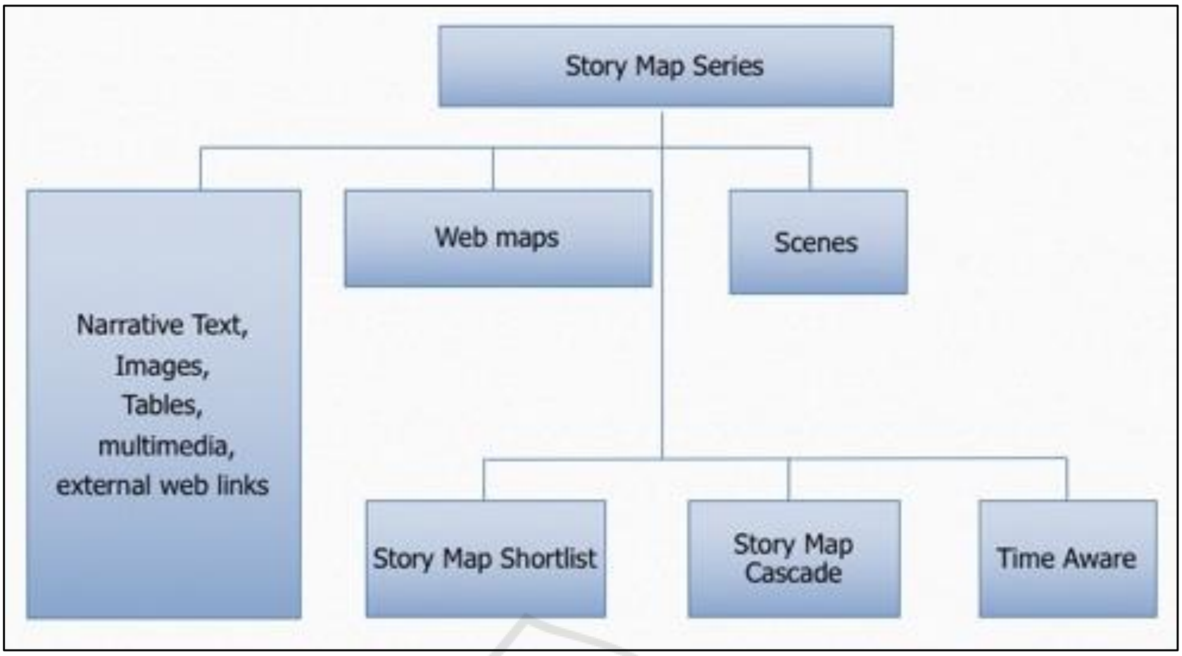

Figure 11: Methana Volcano Story Map structure.

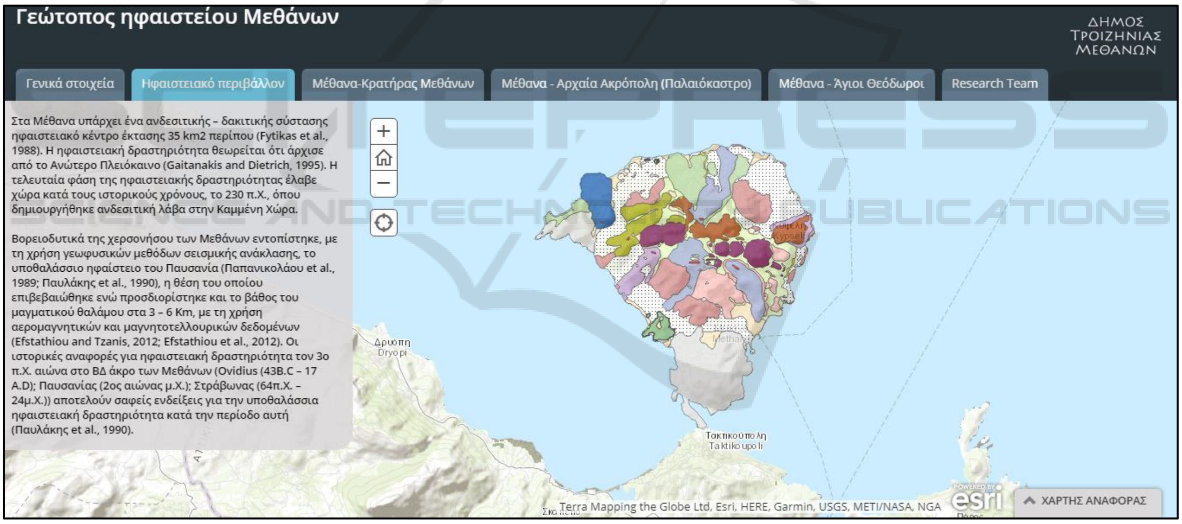

Figure 12: Representative Screenshot of the Story Map.

In conclusion, Methana Volcano Story Map portrays a good example of a web map, while providing information to a wide audience, developing the interest and possibly motivating the public to learn more (or even to visit) about the display area.

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